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22 February 1980

USSR Report

ENGINEERING AND EQUIPMENT

(FOUO 2/80)

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JPRS L/8945

22 February 1980

USSR REPORT

ENGINEERING AND EQUIPMENT

(FOUO 2/80)

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HIGH-ENERGY DEVICES, OPTICS AND PHOTOGRAPHY

UDC 535.317.2

EFFECT OF SOURCE BRIGHTNESS INHOMOGENEITY ON THE POSITION OF AN OPTICAL EQUISIGNAL ZONE

Leningrad IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY MV I SSO SSSR PRIBOROSTROYENIYE in Russian Vol 22 No 9, 1979 manuscript received 16 Oct 78 pp 86-91

[Article by A. N. Timofeyev, Leningrad Institute of Precision Mechanics and Optics]

[Text] The effect of the source brightness inhomogeneity of radiation on the accuracy of monitoring curvilinearity by opto-electronic devices in which an optical equisignal zone is used as the measuring base is considered.

Opto-electronic devices (OEU) for three-point monitoring of curvilinearity in which an optical equisignal zone (ORZ) is used as the measuring base have now become widely distributed [1, 2]. The optical diagram of these OEU consist of three parts--illuminating, which creates a radiation flux of the necessary direction and spectral composition, an information part which forms the ORZ in the illuminator beam cross-section and a receiving part which converts the optical signal to an electrical signal.

Following general concepts on the equisignal zone, the ORZ can be determined as the region of intersection of two or several electromagnetic fields of the optical band in which the values of the main informative parameter are equal. Since this informative parameter in most OEU is energy illumination, constant spatial distribution of it must be provided to ensure stability of the ORZ position. The use of real emitters having brightness inhomogeneity causes deformation of the spatial distribution of energy illumination, which leads to deviation of the ORZ position from the calculated position.

Investigation of the effect of radiation source brightness inhomogeneity on the ORZ position is the purpose of the proposed article.

The optical diagram of an OEU can be represented in simplified form by the output opening 1 (Figure 1) of the illuminating part, a modulator 2

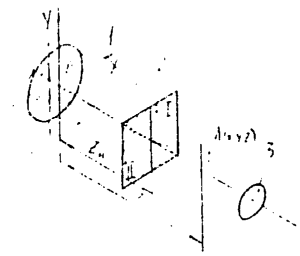

Figure 1. Simplified Diagram of OEU

consisting of two halves I and II, transmission in which varies in time from 0 to 1 strictly in counterphase, and the input opening of the receiving part 3. Let us assume that the origin of reading the coordinate system is combined with the center of opening 1, the main plane XOY coincides with the plane of the output opening and the OZ axis is aligned in the direction of beam propagation. A modulator 2 whose division line of halves I and II passes through the OZ axis and perpendicular to the OX axis is located at distance Z_m from the output opening 1. Let us consider the case when the radiation source image is projected into the output opening of the illuminating system, whereas the output opening of the condensing system is focused at a finite distance [3]. Since any emitter brightness inhomogeneity on the surface can be represented by the sum of the harmonic components of brightness [4], it is sufficient to analyze the effect of each harmonic component and then to add the effect of all components.

Let us analyze the effect of brightness inhomogeneity of the type

$$B(x) = B_0 + B_1 \cos \frac{2\pi}{l} (x + \Delta x), \tag{1}$$

where B_0 is the average brightness of the emitting surface, B_1 is the amplitude of brightness variation along the emitting surface and Δx is the initial phase of the variable component of energy brightness.

Following the definition, the ORZ will be the geometric location of points at which energy illumination E_1, created by the illuminator through half I of modulator 2, will be equal to the energy illumination E_2 created by the illuminator through half II of modulator 2, i.e.,

$$E_1 = E_2. \tag{2}$$

Based on the conclusions of [5], for a square opening measuring 2a x 2a, the energy illumination E_1 at the ORZ point can be expressed by the formula

$$E_1 = \tau \int_{-a}^{a} \int_{-a}^{kx_1} \left| B_0 + B_1 \cos \frac{2\pi}{l} (x - \Delta x) \right| z^{-2} \, dx \, dy, \tag{3}$$

where $k = z_m/(z_m - z)$ is the conversion coefficient, τ is the total transmission of the optical part of the OEU, z is the distance from the output opening of the illuminator to the point at which illumination is determined, z_m is the distance from the output opening of the illuminator to the information block and x_1 is the coordinate of the ORZ point and the energy illumination E_2 at the same point in the form

$$E_2 = \tau \int_{-a}^{a} \int_{kx_1}^{a} \left| B_0 + B_1 \cos \frac{2\pi}{l} (x - \Delta x) \right| z^{-2} \, dx \, dy. \tag{4}$$

Making use of the condition of finding the point at ORZ (2) and simplifying somewhat expressions (3) and (4), we find the transcendent equation

$$X + \frac{B_1}{B_0} \sin \left(X - \frac{2\pi}{l} \Delta x \right) = -\frac{B_1}{B_0} \sin \frac{2\pi}{l} \Delta x \cos \frac{2\pi}{l} a, \tag{5}$$

where $X = \frac{2\pi k x_1}{l}$, from which one can find the value of ORZ displacement.

When calculating the accuracy of OEU operation, the maximum error of the ORZ position is of practical interest. To find the value of interest to us, one must take the derivative of function X of equation (5):

$$\cos \left(X - \frac{2\pi}{l} \Delta x \right) = \cos \frac{2\pi}{l} \Delta x \cos \frac{2\pi}{l} a \tag{6}$$

and solve jointly the system of equations consisting of (5) and (6).

Calculations which permitted one to find the dependence of maximum displacement of the ORZ on the ratios of the size of the opening to the length of the period of inhomogeneity at fixed values of the ratio of the variable component of energy brightness to the average brightness, were made with a computer. The indicated functions are presented by the dashed lines in Figure 2. It is obvious from the given graphs that there is no displacement of the ORZ when measuring the opening equal to an even number of the periods of the variable brightness component. Therefore, when designing an OEU having a square output opening, one must strive to see that the size of this opening is an even number of times greater than the size of the period of the variable component of source brightness inhomogeneity expansion, which has the higher amplitude.

If the value of B_1/B_0 does not exceed 0.15, calculation of ORZ displacement (5) can be simplified:

$$X = \frac{B_1}{B_0} \cdot \sin\frac{2\pi}{l}\Delta x\left(1 - \cos\frac{2\pi}{l}a\right), \tag{7}$$

and the error in calculation by the proposed formula comprises less than 1 percent. The maximum displacement of the ORZ for all values will be

$$X_{max} = \frac{B_1}{B_0}\left(1 - \cos\frac{2\pi}{l}a\right). \tag{8}$$

If the output opening of the illuminating part (radius R) is circular, we find

$$\sin\frac{2\pi}{l}\Delta x\int_0^1 \sqrt{1-r^2}\sin\frac{2\pi R}{l}r\,dr = \frac{B_0}{2B_1}\left(r_1\sqrt{1-r_1^2} + \arcsin r_1\right) + \int_0^{r_1}\sqrt{1-r^2}\cos\frac{2\pi R}{l}\left(r - \frac{\Delta x}{R}\right)dr, \tag{9}$$

where $r = \frac{kx}{R}$, $r_1 = \frac{kx_1}{R}$.

To find the maximum value of ORZ displacement, one must take the derivative of function r_1:

$$\cos\frac{2\pi}{l}\Delta x\int_0^1 \sqrt{1-r^2}\sin\frac{2\pi R}{l}r\,dr = \int_0^{r_1}\sqrt{1-r^2}\sin\frac{2\pi R}{l}\left(r - \frac{\Delta x}{R}\right)dr \tag{10}$$

and solve the system of equations (9) and (10).

The values of the maximum displacement of the ORZ were found from expressions (9) and (10) by using a computer. The results of the calculations for the two values of the ratio of the variable component of energy brightness to the average brightness are represented by the solid lines in Figure 2. Analysis of the graphs permits one to conclude that there is no position for a round output opening in which the maximum value of ORZ displacement would be equal to zero.

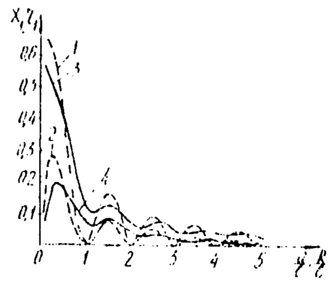

Figure 2. Dependence of Maximum Displacement of ORZ on Value of Ratio of Size of Opening to Length of Period of Brightness Inhomogeneity: curves 1 and 2 were found for a square output opening and those for 3 and 4 were found for a round opening at $B_1/B_0 = 1$ and $B_1/B_0 = 0.4$

In practice when $B_1/B_0 \leqslant 0.15$, calculation of the extent of ORZ displacement can be carried out by the formula

$$r_1 = T(R/l)\,\frac{B_1}{B_0}\sin\frac{2\pi}{l}\,\Delta x, \tag{11}$$

where $T(R/l) = \int_0^1 \sqrt{1-r^2}\,\sin\frac{2\pi R}{l}\,r\,dr.$

The values of function T(R/1) are determined and represented by the graph of Figure 3 for simplification of engineering calculations by formula (11).

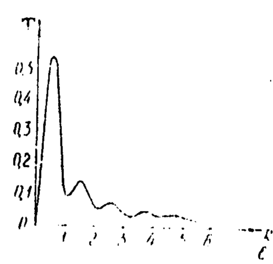

Figure 3. Graph of Function T(R/1)

The law of brightness energy distribution B in the direction of winding of the filament (coordinate axis OX_i) can be approximated by the following expression for movie projector and aircraft filament lamps, based on the results of photometric evaluation of sources carried out by the author,

$$B = B_0 - B_1 \sin\left(\frac{2\pi}{b} x_i - \arccos\frac{2}{\pi}\right) + B_2 \sin\frac{\pi n x_i}{b},$$

where 2b is the width of the filament body, B_0 is the average brightness of the emitting surface, n is the number of complete spirals of the filament on width 2b, B_1 is the amplitude of brightness variation with frequency $2\pi/b$, B_2 is the amplitude of brightness variation with frequency $\pi n/b$, x_i is the coordinate of the point on the emitting surface and for movie projector tubes $B_1 = (0.1-0.15)B_0$ and $B_2 = (0.03-0.06)B_0$ and for aircraft lamps $B_1 = (0.25-0.35)B_0$ and $B_2 = 0.05-0.09)B_0$. Light diodes, which are finding ever wider use in OEU, have brightness distribution

$$B = B_0 + B_1 \sin\left(\frac{\pi}{2b} x_i - \arccos\frac{2}{\pi}\right),$$

and $B_1 = (0.1-0.2)B_0$ for the most powerful AL107B light diodes. Using the expressions found above, it is easy to calculate that the maximum ORZ displacement may comprise 0.6 mm when using the indicated sources for k = 1, R/l = 1.5 and R = 30 mm in OEU, which again confirms the need to take into account the effect of radiation source brightness inhomogeneity.

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NAVIGATION AND GUIDANCE SYSTEMS

UDC 531.383

LEVELLING AND GYROCOMPASS NAVIGATION OF GYRO-STABILIZED PLATFORM USING SUBOPTIMAL FILTERS

Leningrad IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY MV I SSO SSSR PRIBOROSTROYENIYE in Russian Vol 22 No 9, 1979 manuscript received 7 Feb 79 pp 61-65

[Article by G. S. Korolev and G. V. Tyumeneva, Leningrad Institute of Aviation and Instrument Building]

[Text] The problem of using some suboptimal filters produced by simplification of a Kalman filter for levelling and gyrocompass navigation of a gyro-stabilized platform is considered. The equations of motion of the system are presented and the comparative accuracy of the considered filters is estimated by simulation on the M-220M digital computer.

The automatic display devices of a gyro-stabilized platform include those for levelling and those for azimuth display [2]. In the case of independent display of the nort and east channels, the equations of motion of the platform for the first of them in the absence of accelerations can be written in the form

$$\dot{\beta}=\delta\beta-(U+\dot{\lambda})\cos\varphi\cdot\gamma-\frac{\Delta V_N}{R}-K_1\cdot Z,\quad \dot{\gamma}=\delta\gamma+(U+\dot{\lambda})\cos\varphi\cdot\beta+K_2\cdot Z,$$
$$\Delta\dot{V}_N=\Delta d_N+g\beta-K_3\cdot Z. \qquad (1)$$

Here U is the angular velocity of the earth's rotation, R is the earth's radius, φ is latitude, λ is longitude, β is the error of levelling the platform, γ is the gyrocompass navigation error, $\delta\beta$ is the rate of drift of the levelling gyroscope, $\delta\gamma$ is the rate of drift of the azimuth gyroscope, ΔV_N is the error of generation of the north velocity component, Δd_N is the zero displacement of the north accelerometer, g is the acceleration of gravity, K_1, K_2 and K_3 are some coefficients in the platform correction circuit, Z is the difference signal determined in the case of correction of the system from an external rate meter by the relation

$$Z = \Delta V_N + V_E \cdot \gamma - \Delta V_{NU}, \tag{2}$$

V_E is the east velocity component of motion of the object and ΔV_{NU} is the error of measuring the north velocity component of the object by the external meter. Let us call values β, γ, and ΔV_N, which characterize the position of the gyro-stabilized platform with respect to the true horizon, the directions to north and the error of measuring absolute velocity the main navigation parameters. The amplification factors K_1-K_3 are usually selected as constant to find the required time of the transition process, accuracy and so on. It is further suggested that suboptimum filters of different type, obtained by simplification of a Kalman filter, be used for display purposes [1].

During the investigation, let us use the following model of disturbances of the gyro-stabilized platform and errors of the external rate meter:

--the rate of gyroscope drift

$$\delta\beta = \delta\beta^0 + \delta\beta^s(t), \quad \delta\gamma = \delta\gamma^0 + \delta\gamma^s(t), \tag{3}$$

where $\delta\beta^0$ and $\delta\gamma^0$ are the constant components of the drift rate characterized by the mean square values σ_β^0 and σ_γ^0 and $\delta\beta^s(t)$ and $\delta\gamma^s(t)$ are the random components with exponential correlation functions characterized by mean square values σ_β and σ_γ and by attenuation factors μ_β and μ_γ;

--zero displacement of the accelerometer

$$\Delta d_N = \mathrm{const}; \tag{4}$$

--the error of measuring the north velocity component with respect to the log

$$\Delta V_{NU} = \Delta V^0_{NU} + \Delta V^s_{NU}(t) + V(t), \tag{5}$$

where ΔV^0_{NU} is the constant component with mean square value σ_{V^0}, $\Delta V^s_{NU}(t)$ is the random low-frequency component with exponential correlation function having parameters σ_N and μ_N; and V(t) is the random high-frequency component of the velocity measurement error approximated by white noise of intensity R_{sh}.

The vector of state of the system with regard to equations of the gyro-stabilized platform (1) and error equations (3)-(5) is written in the form:

$$\begin{gathered}\dot{\beta}=\delta\beta^0+\delta\beta^c(t)-(U+\dot{\lambda})\cos\varphi\cdot\gamma-\frac{\Delta V_N}{R},\quad \dot{\gamma}=\delta\gamma^0+\delta\gamma^c(t)+(U+\dot{\lambda})\cos\varphi\cdot\beta, \\ \Delta\dot{V}_N=\Delta a_N+g\beta,\ \delta\dot{\beta}^0=0,\ \delta\dot{\gamma}^0=0,\ \Delta\dot{V}^0_{NU}=0, \\ \delta\dot{\beta}^c(t)=-\mu_\beta\cdot\delta_\beta^c(t)+\sqrt{2\sigma_\beta^2\cdot\mu_\beta}\,q_1(t), \\ \delta\dot{\gamma}^c(t)=-\mu_\gamma\cdot\delta_\gamma^c(t)+\sqrt{2\sigma_\gamma^2\cdot\mu_\gamma}\,q_2(t), \\ \Delta\dot{V}^c_{NU}(t)=-\mu_N\cdot\Delta V^c_{NU}(t)+\sqrt{2\sigma_N^2\cdot\mu_N}\,q_3(t),\ \Delta\dot{a}_N=0.\end{gathered} \tag{6}$$

Here $q_1(t)$-$q_3(t)$ are white noise which form errors having exponential correlation functions.

As follows from system of equations (6), Kalman's method [1] requires introduction of an additional seven parameters which describe the errors of the primary sensors of the gyro-stabilized platform and the external rate meter in addition to the first three main navigation parameters β, γ and ΔV_N, which entirely comprises a tenth-order vector. The correlation matrix of the estimated values and the matrix of the weighting coefficients in the Kalman filter have a correspondingly high dimension (up to 10 X 10, inclusively). The effects of this order on the matrices require a greater volume of internal storage of the STsVM [Digital computer system] and considerable machine time. Moreover, the limitation of the STsVM digit matrix, manifested, for example, in disruption of the symmetry of correlation matrices, begins to be felt with these orders of the matrices. Modelling of the display problems of a gyro-stabilized platform with Kalman filter shows that inclusion of the lower seven parameters of vector of state (6) among the analyzed parameters yields only a slight increase in the accuracy of determining the main navigation parameters (vertical, speed and course), but considerably complicates the processing algorithm. A suboptimal filter which takes into account all the component vectors of state (6) without introduction of estimated parameters in them can be synthesized according to the foregoing [1]. This suboptimal filter [1] is distinguished from a Kalman filter only by the matrix which takes into account the correlation between the vectors of estimated and unestimated parameters occurring as a result of joint processing.

The suboptimal filtration algorithm for the display problem of a gyro-stabilized platform was simulated on the M-220M digital computer and it was compared to an optimum Kalman filter. Two version of the suboptimal algorithm--the first with analysis of only the three main navigation parameters and the second with analysis of the main navigation parameters and the constant gyroscope drift rates--was considered in this case. A considerable number of calculations was carried out and the parameters of the correlation functions of errors of the sensors of the gyro-stabilized platform and the external rate meter varied within the range determined by experimental data. Some of the typical results of modelling are presented in Figures 1 and 2.

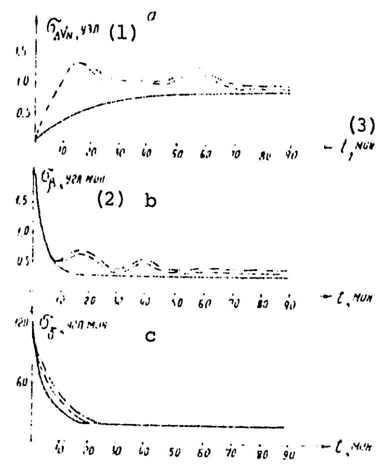

Figure 1. Mean Square Errors of Determining Speed (a), Vertical (b) and Heading (c)

Key:
1. Knots
2. Angular minutes
3. Minutes

The mean square errors of generation of velocity (a), vertical (b) and heading (c) in systems with a Kalman filter (solid line), a suboptimal filter with five analyzed components (dashed line) and a suboptimal filter with three main analyzed components (the dot-dash line) of the vector of state (6) are given in Figure 1. The variable amplification factors in the platform correction circuits for velocity (a), vertical (b) and heading (c) for the same correcting filters as in Figure 1 are presented in Figure 2.

The case considered in Figures 1 and 2 corresponds to the following input data on gyroscope drift and accelerometer and rate meter errors: $\sigma_\beta(0) = 2$ angular minutes (it is assumed that the platform was initially set sufficiently accurately to the horizon); $\sigma_\gamma(0) = 120$ angular minutes (data on heading at the initial moment of time come, for example, from the magnetic compass); $\sigma_{\Delta V_N}(0) = 0$ (display is accomplished with precisely known initial speed of the object), $\varphi = 60°$, $V_N = V_E = 0$; $\sigma_\beta^0 = 0.03$ angular minutes/min; $\sigma_\gamma^0 = 0.07$ angular minutes/min; $\sigma_\beta = 0.01$ angular minutes/min; $\sigma_\gamma = 0.03$ angular minutes/min; $\sigma_{\Delta d_N} = 10^{-4}$ g; $\sigma_{V0} = 0.2$ knot; $\sigma_N = 1$ knot; $\mu_N = 0.01$ 1/min; $\mu_\beta = \mu_\gamma = 0.01$ 1/min; and $R_{sh} = 0.1$ knot^2·min.

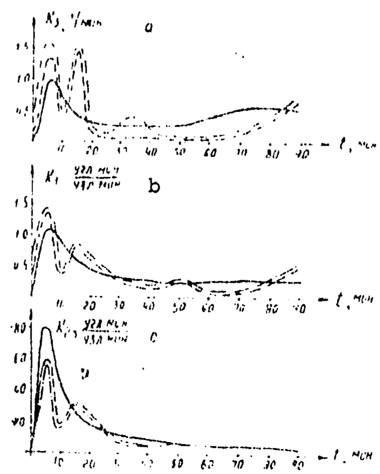

Figure 2. Variable Amplification Factors in Platform Correction Circuits

Comparison of the curves of the mean square errors presented in Figure 1 shows that the optimum and suboptimum algorithms differ slightly in the accuracy of generation of the vertical and heading, which indicates the feasibility of converting to suboptimum algorithms to simplify the problems being solved and to reduce the volume of calculations on the digital computer. In this case the volume of calculations upon conversion to suboptimum algorithms is reduced by a factor of 2-3 compared to optimum algorithms. Optimum and suboptimum algorithms differ in the conversion mode approximately twofold by time of 10-20 min in the accuracy of speed generation, while speed is then determined with accuracy up to the error of the external rate meter. The transition processes by vertical and heading are completed within 10-20 minutes. The type of conversion coefficients in the platform correction shows that they can be approximated, for example, by parabolic or step time functions.

Let us consider a suboptimum filtration algorithm having three main estimated navigation parameters β, γ and ΔV_N. Let us approximate the coefficients K_1-K_3 corresponding to this case by the step functions presented in Figure 3: by one step (a) and by two steps (b). Let us take the maximum values of the suboptimum amplification factors from Figure 2 for t_1 = 5 min and t_2 = 15 min as the values of the constant coefficients of each of the steps. We note that the values of the used amplification factors correspond to the stable operating mode of closed system (1).

Modelling shows that the transition processes for cases of realization of suboptimum coefficients and coefficients approximated by single-step functions in the platform display circuit differ by no more than 10-15 percent.

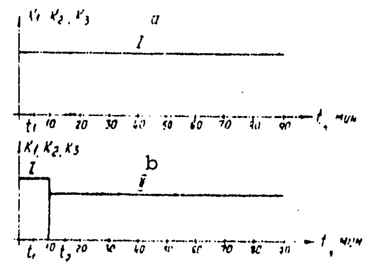

Figure 3. Step Amplification Factors in Platform Correction Circuits: I--K_1 = 1.3 angular minutes/knots per minute; K_2 = -59 angular minutes/knots per minute; K_3 = 1.63 1/min; II--K_1 = 0.78 angular minutes/knots per minute; K_2 = -30 angular minutes/knots per minute; K_3 = 1.55 1/min

Approximation by two steps permits one to find the practically optimum reduction of a gyro-stabilized platform (the transition processes differ from those of a filter having three estimated components by not more than 2-5 percent).

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PUBLICATIONS

UDC 533.9

ADIABATIC COMPRESSION OF PLASMA IN THE TOKAMAK

Leningrad ADIABATICHESKOYE SZHATIYE PLAZMY V TOKAMAKE (Adiabatic Compression of Plasma in the Tokamak) in Russian 1979 signed to press 18 May 79 p 2, 174-176

[Annotation and table of contents from book by Mark Grigor'yevich Kaganskiy, Izdatel'stvo "Nauka", 1, 150 copies, 176 pages]

[Text] This book is devoted to a description of experiments on the adiabatic compression of the plasma pinch in the tokamak by means of increasing the magnetic field. It is shown that the compression leads to a considerable heating up of the plasma and an improvement of its thermal insulation. A great deal of attention is paid to the technique of the experiments. A comparison is made between the results obtained and the results of other work. Long-range compression prospects for large toroidal units are analyzed. Bibliography--190 titles, illustrations--95, tables--9.

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PUBLICATIONS

USSR

UDC 626.022 (260)

MACHINES AND MECHANISMS FOR UNDERWATER OPERATIONS

Leningrad MASHINY I MEKHANIZMY KLYA PODVODNYKH RABOT (Machines and Mechanisms for Underwater Operations) in Russian 1979 signed to press 7 Feb 79 p 2, 190-192

[Annotation and table of contents from book by Vadim Leonidovich Baladinskiy, Vyacheslav Anatol'yevich Lobano, and Boris Aleksandrovich Galanov, Izdatel'stvo "Sudostroyeniye," 1979, 3,000 copies, 192 pages]

[Text] This book sums up Soviet and foreign materials on various types of machines and mechanisms for underwater operations. It sets forth the basic positions of the theory of dynamic disaggregation of soils and illustrates them with examples. It examines the design of the machines, mechanisms, and manual tools which are utilized in building underwater structures, dredging operations, and laying communications. It cites the necessary data on measures for environmental protection while carrying out underwater operations. The foundation of this book consists of description of the designs of Soviet machines, including those created with the authors' participation.

This book is intended for engineers and technicians who are working in the field of creating underwater construction machines and using them to build various facilities on the bottoms of seas, lakes, and rivers. The contents of the book may be of interest to workers in the maritime or river fleets who are concerned with problems of dredging operations, as well as students of construction and hydraulic engingeering facilities at institutions of higher learning.

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